

Base Heating Testing Improvements

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All multi-engine launch vehicles experience heating near the aft end (base) during ascent, induced by the hot exhaust plumes of the propulsion system. These heating environments are important to the vehicle design because they determine the weight, cost, and complexity of the thermal protection system (TPS) for the vehicle base region and engines. This effort developed innovative base heating test techniques and base heating model designs which will dramatically lower test cost, reduce test time, and significantly improve launch vehicle design. Emphasis was placed on using off-the-shelf hardware in designing rather than specialty items. These test improvements are generic and fully adaptable to the X-33 Reusable Launch Vehicle design concept currently selected for a flight demonstration program.

The effort produced a series of products leading to laboratory cold flow demonstration hardware to validate the proposed new testing innovations as illustrated in figures 56 and 57. The X-33 propulsion system and geometry data were reviewed to develop base heating testing requirements. Potential test facilities were evaluated and a cost benefit analysis was performed for each facility. A new test hardware design specification spreadsheet analysis method was developed and utilized for a generic design application. A transient hot firing analysis PC-based code was implemented to verify the transient start-up behavior of the chosen generic design. An AutoCad solid model of the new selected design was produced based on the design specifications spreadsheet. This solid model was used by the Alabama Industrial Development Training Center to produce a rapid prototype of the internal flow passages using stereolithography. Visual inspection

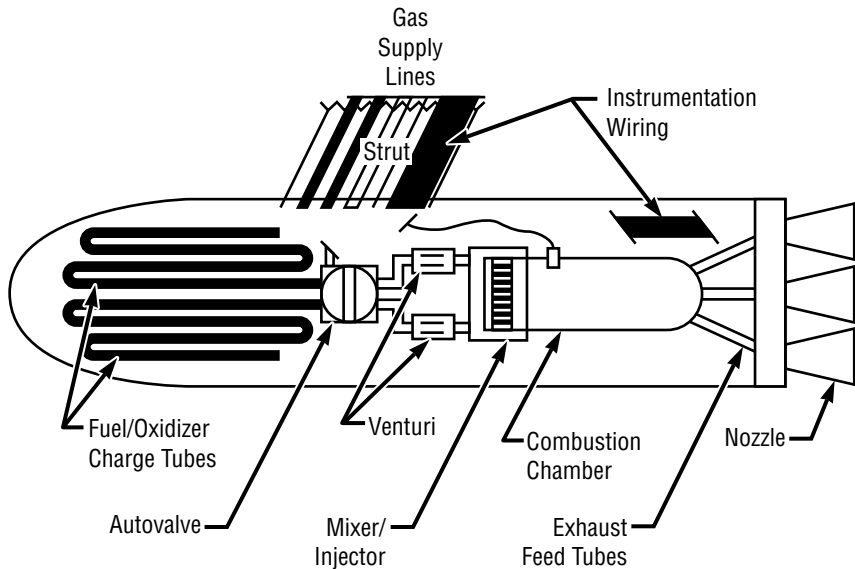


FIGURE 56.—Existing short duration hot flow propulsion simulation system.

and measurement of this solidified resin physical model verified the AutoCad solid model design. A new simpler nozzle gimbal

mechanism was devised, designed and verified using the rapid prototyping method. A demonstration cold flow model was then

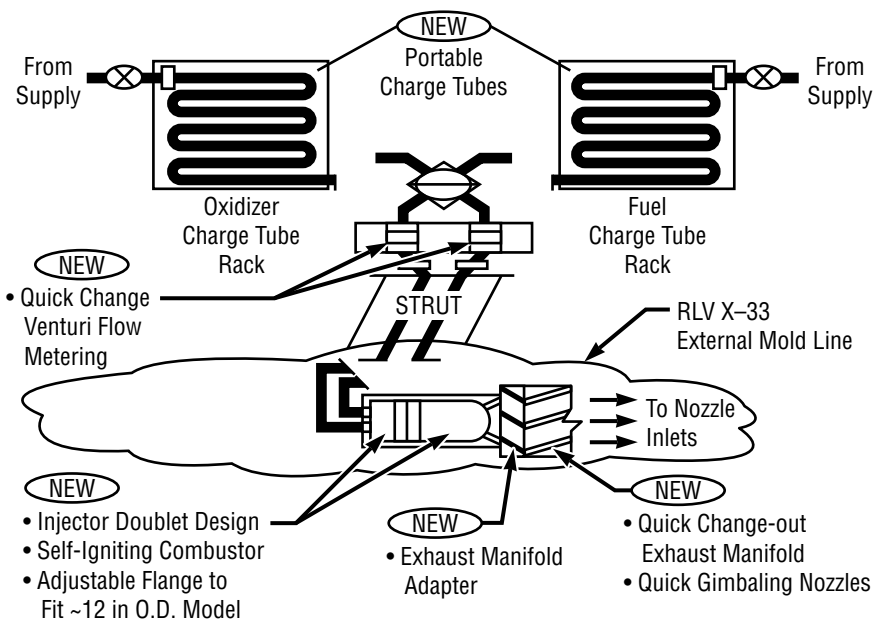


FIGURE 57.—Innovative Qualis short-duration hot flow propulsion simulation system.

designed, fabricated and tested. The test results provided the experience and evidence that hot flow tests could be accomplished quicker and much cheaper. Primary findings included:

- Flexible off-the-shelf tubing was found easy to work with and provided an excellent charge tube. Internal variations with the charge tube diameter had no effect on charge tube performance;
- A buffer gas can be used to shorten the hydrogen tube as demonstrated by the nitrogen buffer gas used with helium. External charge tubes reduce model complexity and cost;
- Long run times of 100 to 150 msec have been demonstrated with the current charge tubes compared with 30 to 60 msec in the past. The low cost and low volume of coiled charge tubes makes almost any run time feasible. Thus, increasing the reliability of base heating test data;
- A current off-the-shelf solenoid valve with an opening time of approximately 20 msec appeared to be quite adequate to control the charge tube flow. This eliminates the need for costly one-of-a-kind auto valve designs for new launch vehicle concepts;
- Experience showed that a simple six-bolt attachment method provided a quick and simple method for making model modifications; and
- The data obtained demonstrated that a two-dimensional flow aerospoke geometry can be supplied from a central manifold even when fine geometric tolerances are involved. Multiple axisymmetric conventional nozzle firings had been demonstrated previously.

Short-duration hot flow testing can be the cost effective testing technique of the future for a variety of plume, base heating, plume impingement, combustion studies and computational fluid dynamics (CFD) verification work.

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Biographical Sketch: Dr. Seaford is an engineer in the Fluid Dynamic Analysis Branch at MSFC's Structures and Dynamics Laboratory. He is currently responsible for generating launch vehicle base thermal design environments and developing improved plume flowfield and plume-induced environments methodology. He is currently responsible for defining X-33 and X-34 thermal design environments. Seaford earned his Ph.D. in aerospace engineering from the North Carolina State University, Raleigh, NC, in 1983 and has been employed by NASA for the last 12 years. 